Technology Assessment in Support of Pilot New Commercial Building Demand-Side Management Program

Michael J. Holtz, C. Edward Hancock, Peter C. Jacobs and
David R. Roberts, Architectural Energy Corporation
Robert D. Westby, National Renewable Energy Laboratory
Jane L. Finleon, Public Service Company of Colorado

Public Service Company of Colorado is currently investigating the design and implementation of demand-side management programs (DSM) in the commercial building sector. Three commercial building types are considered as part of a pilot commercial DSM program: low-rise office, retail, and light industrial. The energy savings and costs associated with incrementally improving the current Boulder (Colorado) Energy Code (ASHRAE 90A-80) to ASHRAE 90.1 are established. In addition, the costs and benefits of exceeding the ASHRAE 90.1 levels of energy performance are determined for selected DSM measures.

The energy performance of the buildings was determined using the DOE 2.1 simulation program. For each DSM measure, the cost of installing the advanced technology instead of the base case technology during original construction was established by cost estimators of the construction company originally responsible for the project. Although the buildings are structurally similar, the effectiveness of the same DSM measures in different buildings varied significantly depending on how the building was used. The technology assessment facilitated a detailed analysis of the economic impact of code adoption and DSM implementation with respect to (1) the building community, (2) economic competitiveness, and (3) community level economic benefits.

Lighting measures provided the most favorable economic results for each building. The relatively high cost of most envelope measures generally could not be justified by the low savings achieved. The impact of changing from the present energy code to ASHRAE 90.1 was found to be relatively low both in terms of the cost of modifications to the buildings and in terms of energy savings.

Introduction

Integrated resource planning, also known as least-cost utility planning, enables utilities to evaluate on a relatively equal basis the benefits and costs of supply-side and demand-side resource alternatives. In many cases demand-side resources, in the form of energy-efficiency improvements to lighting, appliances, motors, and HVAC equipment, are less costly to obtain than supply-side resources. However, uncertainty exists on the magnitude, reliability, and cost of these demand-side resources. In response to this uncertainty, Public Service Company of Colorado (PSCo) has initiated a number of demand-side management (DSM) pilot projects to analyze and field test integrated packages of high-efficiency end-use technologies in selected commercial customer facilities. The assumption or hypothesis of these pilot projects is that substantial energy savings can be achieved at reasonable costs through the use of commercially available end-use technologies acceptable to the customer.

PSCo has identified new construction of commercial buildings as an important element of its DSM program and has initiated a two-phase pilot program for the Boulder service area. The intent of Phase I, and the subject of this paper, is to determine the potential for successful application of DSM technologies in several building types representative of present local construction practice. Additionally, the impact of changes in building code requirements for energy efficiency is analyzed.

This paper presents the results of the analysis of various energy-saving measures that may be cost-effective from the utility perspective and acceptable to the customer. The goal of the project was to identify those energy-saving measures that support PSCo resource planning objectives within specified economic performance criteria. For those measures which pass this screening, PSCo may develop incentives to encourage their inclusion in the design of commercial buildings in Phase II of the project.

Technical Approach

The overall technical approach to establishing the costs and benefits of various demand-side management options for new commercial buildings involves the energy and economic analysis of these options in recently-constructed commercial buildings in Boulder. Actual buildings, as opposed to hypothetical buildings, were chosen as a starting point for the energy and economic analysis of DSM options for several reasons:

(1) They would represent typical design and construction practice for the City of Boulder.

(2) Construction cost and energy performance data would be available for these projects.

(3) Occupancy information, such as operating schedules, equipment loads, thermostat setpoints, and so on, would be available from an audit of the buildings.

The sample of buildings selected for this study was based on a survey of new commercial buildings constructed in Boulder within the last two years. Three buildings were selected:

Building Type	Building Selected
Low-Rise Office	Two Pearl Plaza
Light Industrial	Two Pearl Plaza
Retail	Meadows Shopping Center

A list of DSM measures was developed based upon previous research and design of energy-efficiency measures in new commercial buildings (AEC 1988). Over 90 energy-saving options were identified in five categories: lighting, HVAC, appliances, electronic control, and envelope. From these, 16 options were recommended for analysis during Phase I. The final list of DSM options selected for Phase I analysis are listed by building type in Table 1.

The energy consumption, electric demand, and utility costs of the three buildings, are calculated using a computer simulation model. An hour-by-hour, dynamic simulation of the building which accounts for the many complex interactions between the environment, building structure, occupants, equipment, lighting, and HVAC is required to accurately predict the peak energy requirements on an hour-by-hour basis. Because of the importance of accurately predicting hourly peak loads, and the inherent complexity of a commercial HVAC system, the DOE-2.1D program (LBL 1984) was selected for this study.

Table 1. List of DSM Measures

DSM Measures	Low-Rise Office	Retail	Light Industrial
Energy-efficient lamp/electronic ballasts	x	x	x
Energy-efficient luminaires	x	x	x
Occupancy sensors	x	x	x
Daylighting controls	x	x	x
Improved electric chillers	x	x	x
High-efficiency motors	x	x	x
Variable speed drives	x		x
Economizer (for unit sizes less than 10 tons)		x	
Evaporative cooling (direct and indirect)	x	x	x
Improved package air conditioners	x	x	x
Gas absorption/engine chiller	x		x
High performance glazings	x	x	x
Envelope insulation		x	x

Base Buildings

The first step in establishing the present performance of each of the buildings is a careful audit of the structure, equipment, building operation, and occupant behavior. Hourly energy consumption is calculated for the base building using the DOE-2.1D computer program. These data are post-processed in order to calculate monthly electric consumption, electric peak demand, and gas consumption. Energy costs are calculated according to the applicable rate structures.

Energy Use Characterization of Base Buildings

The purpose of energy use characterization is to rank the energy end-uses and components of the building relative to their overall energy consumption and cost. A set of DOE-2.1D runs is performed on the base building model to characterize the overall building energy consumption. The base building is simulated to establish a baseline in terms of energy consumption, demand, and cost. Next, selected components of overall building energy consumption, such as illumination, occupants, equipment, ventilation, envelope conduction, and so on, are eliminated, one at a time, from the simulation, and the annual energy consumption, demand, and cost are calculated. The components having significant impact on overall energy consumption and demand will show a significant reduction in the annual energy cost when eliminated from the simulation. This exercise identifies the important factors in overall building energy consumption and points to solutions (DSM measures) that can make the greatest impact on reducing energy consumption, demand, and operating costs.

An example of the results of the energy use characterization study for the low-rise office are shown in the bar chart in Figure 1. These results clearly indicate that lighting and office equipment provide opportunities for improved efficiency, while reducing heat transfer through walls and windows will have minimal impact on annual energy consumption for this building.

Code Compliance Analysis

Present and proposed energy-efficiency code requirements are used as a baseline to which the performance of DSM measures are compared. The as-built construction of each building is checked for compliance to the present Boulder energy code (CABO 1989). Since ASHRAE Standard 90.1-1989 (ASHRAE 1989) is being considered for adoption in the City of Boulder, the incremental changes from present code requirements necessary to achieve compliance to ASHRAE 90.1-1989 are analyzed. Energy savings and cost estimates for measures required by the proposed change are used in evaluating the costs and benefits. The analysis of DSM measures in the enhanced building are compared to the new ASHRAE 90.1 base case.

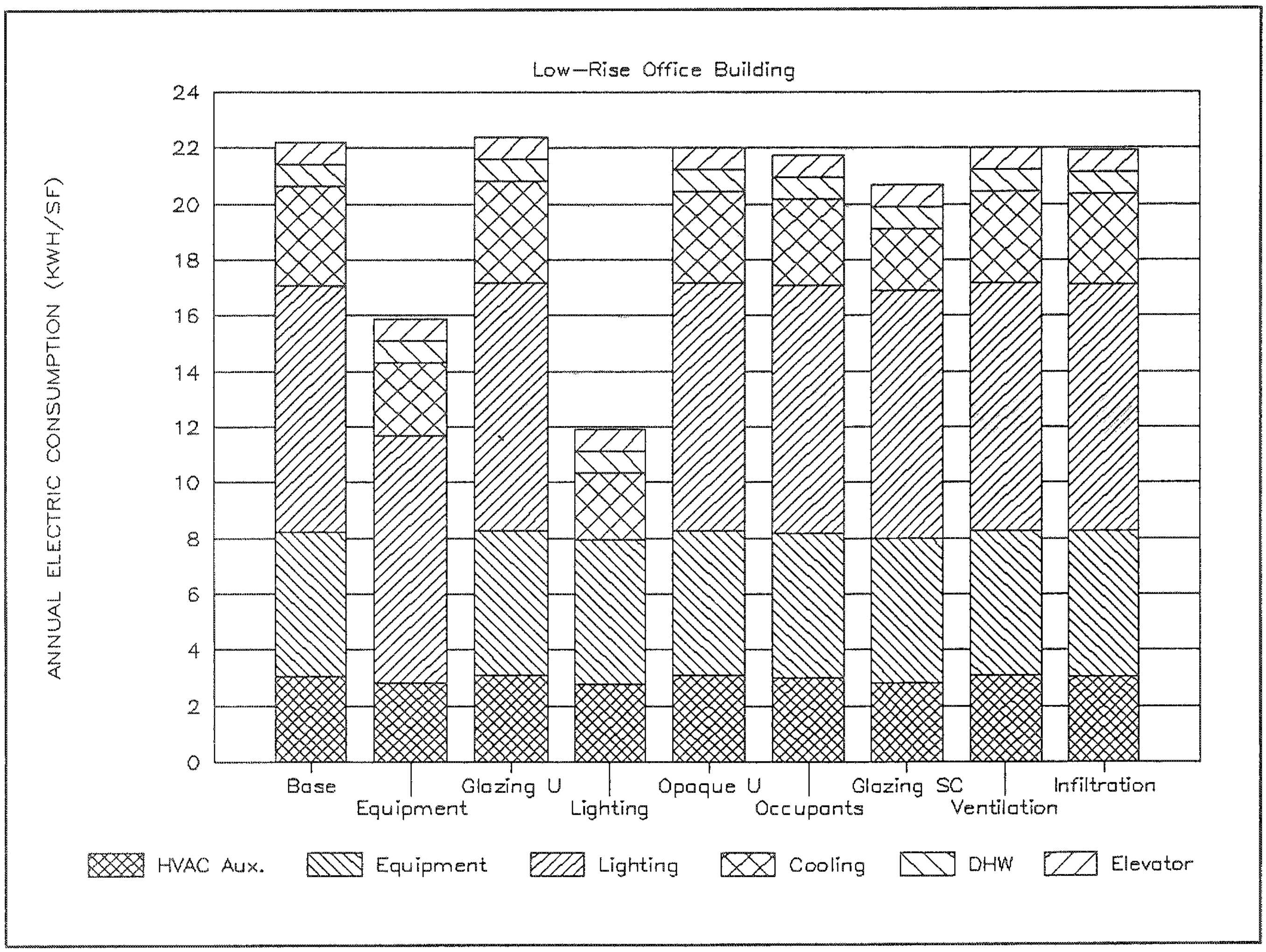

Figure 1. Energy Use Characterization for the Low-Rise Office Building

Enhanced Building Analysis

The selected energy-saving DSM measures are applied one at a time to the base building model, and the simulation is repeated. Energy savings, peak demand savings, and cost savings are calculated by comparing the results of the enhanced building run to the base building run. After evaluating individual measures, packages of measures are evaluated to examine the effects of interactions between measures. Energy-saving measures evaluated in this study include daylighting control, lighting efficiency improvements, HVAC auxiliary and HVAC system efficiency improvements, and envelope improvements.

Cost Estimation

To obtain a high level of confidence in the estimates of costs for each energy-saving measure, the construction companies and subcontractors involved in the original construction of the buildings were asked to provide careful estimates of the incremental costs for the enhanced building. In most cases, subcontractors were able to refer to original cost estimates for the particular building and replace the base components with enhanced measures. Several economic performance factors are calculated: simple payback (yr.), annual energy savings ($/yr.), cost of saved demand ($/kW), and cost of saved electrical energy (cents/kWh/yr.). It is assumed for purposes of this study that the costs of design, commissioning and maintenance of the DSM measures are identical to the technologies replaced. Thus, the cost shown and the economic performance factors calculated are based on the installed cost of the DSM measures.

Building Characteristics

Low-Rise Office Building

The model for low-rise offices represents the three story portion of the building at Two Pearl Plaza, 4910 East Pearl Circle, in Boulder Colorado. The building is square, 80 feet on each side, providing 6,400 gross square feet on each floor. The height between floors is 13 feet with floor-to-ceiling height of 9 feet and plenum height of 4 feet. The front of the building faces due North. On each floor, insulated glass windows extend from a height of 3.5 feet above the floor to 9 feet around the entire exterior. Opaque exterior walls are insulated to an R-value of 11 and have a light colored brick veneer finish. On the ground floor, an earth berm extends to a height of 3 feet around the entire perimeter and is insulated on the interior of the concrete foundation wall to an R-value of 14.

Operation of the entire building is modeled based on two actual businesses, each one presently leasing approximately half the space on one floor. An audit of these offices was performed to determine the number of people, work schedule, lighting, and office equipment in the building. Each floor is assumed to have identical occupancy.

The building is heated and cooled by two roof-top variable-volume and temperature (VVT) packaged systems. These units have a natural gas furnace and electrically driven direct-expansion cooling with an economizer mode. Each unit has a nominal cooling capacity of 27 tons and heating capacity of 500,000 Btu per hour.

Retail Building

The model for the retail building is a single story building consisting of 14,748 square feet of floor space. The space is located in a shopping center and is adjacent to other retail spaces on two sides. The building is divided into three areas: an open retail area with 11,795 square feet of floor space, several small offices with 1,693 square feet of floor space, and a warehouse with 1,260 square feet of floor space. The front of the building faces north and is 70% glass. The opaque wall is insulated to an R-value of 15. The roof is of a flat built-up design insulated to an R-value of 25. The retail space is illuminated with 4-lamp fluorescent fixtures suspended from the roof deck. The warehouse is illuminated with 8 feet long single lamp fixtures.

The spaces are conditioned by six 5-ton packaged roof-top units. These units are equipped with a gas furnace and direct expansion cooling. The units ventilate the building with constant air volume during the occupied hours and cycle to maintain building temperatures during the unoccupied hours.

Light Industrial Building

The model for the light industrial building is the single story portion of the building at Two Pearl Plaza, consisting of 19,680 square feet of floor space. The overall dimensions of the rectangular building are 80 feet by 250 feet with the longer axis running east and west. The building has a flat built-up roof insulated to a R-value of 15. A suspended acoustic ceiling is present in all spaces except manufacturing. The exterior walls are earth-bermed to a height of 3.5 feet against a concrete wall insulated to an R-value of 14. The walls are glazed with insulated glass from the top of the berming to height of 9 feet. The walls above the glazing have a light colored brick exterior and are insulated to an R-value of 11. A portion of the southern exterior wall adjacent to the manufacturing space is not bermed and has no windows. This section of wall is made up of a light-colored brick and is insulated to an R-value of 11.

Manufacturing and assembly processes occupy 5,580 square feet of the building. There are no windows in the space, but there are two roll-up delivery doors. This space is illuminated with suspended fluorescent fixtures and a small number of task lights. The balance of the building space consists of offices, conference rooms, corridors, and open office space. Except for the manufacturing area, the perimeter of the building consists of small offices. The building is ventilated and conditioned by three VVT units, each with a capacity of 15 tons cooling. These units have a gas furnace and electrically-driven, direct-expansion cooling with economizer control (100% outside air). The characteristics of the buildings are compared in Table 2.

Results

Code Compliance

Table 3 summarizes performance and cost changes associated with complying with ASHRAE Standard 90.1. For each of the buildings, some modifications to the as-built conditions were required to meet ASHRAE 90.1. If the present code requirements had been met, the cost of meeting ASHRAE 90.1 would be relatively small for each building. However, the energy impact would also be small. The significant areas of non-compliance with ASHRAE 90.1 were lighting and glazing.

DSM Technologies

Results for each building and for each technology are summarized in Tables 4, 5, and 6. In general, the daylighting control and electric lighting technologies are found to be very successful in all of the buildings. Simple payback periods of less than two years and cost of saved demand of less than $300 per kilowatt are achieved for some measures. For HVAC measures, it is clearly difficult to justify changing from a roof-top packaged system to a built-up system due to the much lower initial cost of the packaged systems. Variable speed controllers and high efficiency motors appear to be the most successful HVAC measures for these buildings.

These results indicate that although identical measures are specified, the resulting costs and energy savings can vary significantly. The variation in the effectiveness of lighting measures results from differences in occupancy schedules and behavior of the occupants. For example, in the light industrial building, our on-site audit indicated lights in several rooms were turned off all of the time thus reducing the benefit of improved lighting. A wide variation in the effect of high efficiency motors and variable speed drives is observed depending on the size and type of the base case HVAC system. Glazing measures can also result in large variations in cost of saved demand depending on the orientation of the building to which they are applied. The light industrial building shows poor performance for this measure in part because the majority of its glass faces North.

Table 2. Summary of Building Characteristics

Building	Area sq. ft.	Stories	Glazing Area, %	HVAC System	Lighting W/sq. ft.	Equipment W/sq. ft.
Low-Rise Office	19,200	3	44	VVT	2.3	1.1
Retail	14,750	1	25	CV	1.8	0.1
Light Industrial	20,000	1	37	VVT	2.6	0.2

VVT = Variable Volume and Temperature CV = Constant Volume

Table 3. ASHRAE 90.1 Code Compliance Cost-Benefit Analysis

Description	Measures Cost ($)	kW Savings (kW)	kWh Savings (kWh/yr)	Electric Savings ($/yr)	Gas Savings ($/yr)	Total Savings ($/yr)	Simple Payback (yr)	Demand Reduction ($/kW)
Low-Rise Office Building	6,020	9.3	13,648	1,035	511	1,546	3.89	645
Retail Building	1,715	0.4	-800	-35	223	188	9.12	4,193
Light Industrial Building	5,275	17.4	32,670	2,203	251	2,454	2.15	302

Table 4. Summary of Demand-Side Management Cost-Benefit Analysis, Low-Rise Office Building

Description	Cost ($)	kW Savings (kW)	kWh Savings (kWh/yr)	Electric Savings ($/yr)	Gas Savings ($/yr)	Total Savings ($/yr)	Simple Payback (yr)	Demand Reductions ($/kW)
Lighting								
Daylighting Controls	5,076	14.7	39,342	2,587	-173	2,414	2.10	344
High Output Lamps	2,700	9.3	29,597	1,807	-132	1,675	1.61	291
Electronic Ballast, T8	6,075	21.0	65,280	4,017	-284	3,733	1.63	289
Parabolic Fixture	13,725	21.0	65,280	4,017	-284	3,733	3.68	289
Occupancy Sensors	3,780	4.7	9,735	784	-44	740	5.11	800
HVAC								
High Efficiency Motors	1,148	0.2	817	41	0	41	28.00	5,740
Improved Seer HVAC	21,600	12.7	11,763	1,168	0	1,168	18.49	1,701
Variable Speed Drive	13,874	5.5	30,244	1,400	-117	1,283	10.81	2,511
Elec Chiller, Built-up	58,000	13.8	-19,331	-155	1,325	1,170	49.57	4,189
Indirect Evap, Built-up	113,000	26.5	-2,838	1,195	1,316	2,511	45.00	4,259
Absorp Chiller, Built-up	81,000	37.1	19,260	2,586	201	2,787	29.06	2,186
Envelope								
Heat Mirror ™Glazing	10,884	6.1	8,962	686	157	843	12.91	1,774
Packages								
Package 1	28,228	29.8	101,304	5,926	-451	5,745	5.17	950
Package 2	39,172	33.1	105,373	6,393	-269	6,124	6.40	1,182
Package 3	26,668	33.5	110,820	6,563	-487	6,076	4.39	796
Package 4	37,552	37.3	114,845	6,998	-310	6,668	5.61	1,007

Table 5. Summary of Demand-Side Management Cost-Benefit Analysis, Retail Building

Description	Cost ($)	kW Savings (kW)	kWh Savings (kWh/yr)	Electric Savings ($/yr)	Gas Savings ($/yr)	Total Savings ($/yr)	Simple Payback (yr)	Demand Reductions ($/kW)
Lighting								
Daylighting Controls	752	3.7	8,942	557	-63	494	1.52	203
High Output Lamps	1,676	7.2	22,064	1,333	-164	1,169	1.43	234
Electronic Ballast, T8	3,591	15.7	48,547	2,936	-377	2,559	1.40	228
Parabolic Fixture	8,113	15.7	48,547	2,936	-377	2,559	3.17	228
Occupancy Sensors	420	1.1	4,825	240	-31	209	2.01	386
HVAC								
Economizer	3,450	0.0	2,527	70	0	70	49.29	--
High Efficiency Motors	718	0.6	2,020	126	0	126	5.70	1,149
Improved SEER	12,000	2.1	1,372	147	0	147	81.63	5,825
Indirect Evap, DX	12,000	15.8	9,451	966	0	966	12.42	761
Indirect-Direct Evap	8,400	16.6	11,080	1,187	0	1,187	7.08	505
Envelope								
Heat Mirror ™Glazing	2,487	1.1	252	56	100	156	15.94	2,292
Improved Roof Insul	2,172	0.4	-105	1	64	65	33.42	5,272
Low E Glazing	590	0.0	-774	-47	106	59	10.00	---
Packages								
Package 1	9,251	20.1	60,863	3,740	-467	3,273	2.83	460
Package 2	11,738	21.1	61,311	3,804	-367	3,437	3.42	557
Package 3	21,251	33.6	67,057	4,490	-467	4,023	5.28	633
Package 4	20,433	30.2	57,592	3,827	-393	3,434	5.95	677

Packages of Measures

The preceding sections describe the effect of measures when they are applied one at a time to the base building. If more than one measure is implemented in the building, the effect of the package of measures may be significantly different from the sum of the effect of the individual measures. In general, the interactions between measures produce savings that are somewhat less than the sum of the savings of individual measures. For example, if occupancy sensors are added to the building that already has improved lamps and ballasts, the savings will be less than if they were added to the base building. To gain some insight into the costs and performance of combinations of measures, several packages consisting of the most successful individual measures from the lighting, HVAC, and envelope categories were analyzed. Table 7 describes which measures constitute selected packages for each building type.

A summary of costs and savings for each package is presented in Tables 4, 5, and 6. These packages produce a simple payback ranging from 4.4 years to 6.4 years and a cost of demand reduction ranging from about $800 to

Table 6. Summary of Demand-Side Management Cost-Benefit Analysis, Light Industrial Building

Description	Cost ($)	kW Savings (kW)	kWh Savings (kWh/yr)	Electric Savings ($/yr)	Gas Savings ($/yr)	Total Savings ($/yr)	Simple Payback (yr)	Demand Reductions ($/kW)
Lighting								
Daylighting Controls	4,797	9.7	27,166	1,719	-298	1,421	3.38	496
High Output Lamps	2,570	7.7	21,650	1,330	-200	1,130	2.27	334
Electronic Ballast, T8	5,455	17.0	47,494	2,916	-497	2,419	2.26	321
Parabolic Fixture	12,322	17.0	47,494	2,916	-497	2,419	5.09	321
Occupancy Sensors	3,290	1.4	5,449	265	-66	199	16.53	2,405
HVAC								
High Efficiency Motors	1,077	0.2	974	43	0	43	25.05	6,225
Improved SEER	18,000	4.5	5,116	445	0	445	40.45	4,044
Variable Speed Drive	9,569	5.2	24,766	1,219	-60	1,159	6.21	1,381
Built-up, Indirect Evap	103,000	9.3	-20,944	-581	180	-401	-256.86	11,135
Built-up, Elec Chiller	92,000	4.7	-24,487	-875	200	-675	-136.30	19,742
Built-up, Absorp Chiller	113,000	12.6	-9,124	201	-638	-437	—	9,450
Envelope								
Heat Mirror ™Glazing	7,951	0.9	3,529	181	410	591	13.45	8,605
Added Insulation	9,000	1.0	1,541	97	290	287	23.26	9,202
Packages								
Package 1	22,883	22.7	74,956	4,267	-592	3,675	6.23	1,010
Package 2	30,834	23.3	76,236	4,350	-143	4,207	7.33	1,324
Package 3	21,633	26.1	82,495	4,815	-672	4,143	5.22	830
Package 4	29,584	26.7	83,766	4,896	-219	4,677	6.33	1,108

about $1200 per kilowatt. The particular packages analyzed here do not necessarily represent an optimal combination of measures for this building. They are intended to show a range of possible results when more than one measure is implemented. Selecting an optimal combination of measures is a complex process that will be strongly dependent on the structure of a DSM program and on the economic position of a particular customer.

Economic Issues

Cost/Benefit Analysis of Code Adoption

The estimate of the city-wide economic impact of adopting ASHRAE 90.1 was completed by extrapolating the cost/benefit analysis of a representative sample of new commercial buildings with five year projections of

Table 7. Description of DSM Packages

	Package 1	Package 2	Package 3	Package 4
Office	parabolic fixture	parabolic fixture	parabolic fixture	parabolic fixture
	occupancy sensors	occupancy sensors	daylighting controls	daylighting controls
	variable speed drive	variable speed drive	variable speed drive	variable speed drive
		Heat Mirror glazing		Heat Mirror glazing
Retail	parabolic fixture	parabolic fixture	parabolic fixture	parabolic fixture
	occupancy sensors	occupancy sensors	daylighting controls	daylighting controls
	high-efficiency motors	high-efficiency motors	high-efficiency motors	indirect-direct evaporation
		Heat Mirror glazing	Indirect-direct evaporation	Heat Mirror glazing
Light Industrial	parabolic fixture	parabolic fixture	parabolic fixture	parabolic fixture
	occupancy sensors	occupancy sensors	daylighting controls	daylighting controls
	variable speed drive	variable speed drive	variable speed drive	variable speed drive
		Heat Mirror glazing		Heat Mirror glazing

Boulder's annual growth rate and building use type. Cost and performance estimates from Table 3 are used in the following analysis.

Several important issues regarding adoption of ASHRAE 90.1 must be taken into account from the City of Boulder perspective including: (1) the economic impact of code adoption on the building community, (2) the implications for economic competitiveness in adopting an updated energy code, and (3) the overall community level economic benefits.

The first cost investment required of the building community to achieve compliance is relatively minor when compared to the total first cost of commercial construction. Further, the incremental first costs are more than offset by the resulting savings. The net present value (NPV) of costs and savings are determined by applying the economic assumptions in note (1) to the cost and performance results presented in section 6.1. and appropriately multiplying this by the expected amount of construction activity for each building type. The NPV of incremental cost is $427,000 (or $0.223 per square foot), and the NPV of savings is $1,020,000 (or $0.575 per square foot). The estimates assume a five year period during which the ASHRAE 90.1 code would be in effect. The efficiency measures required for compliance were determined to have a 20 year life. The annual demand reduction is 84.2 kW or 421 kW after five years. The reduction in electricity use is 192,951 kWh per year.

The adoption of a new code may have an impact on construction costs in Boulder relative to surrounding areas that may not adopt such a code. Given that the estimated incremental cost to achieve compliance is less than $0.25 per square foot, it appears that competitiveness should not be a significant issue. The resulting savings of $0.57 per square foot should be reflected in lower building operating costs and could prove to be a selling point in favor of siting construction in Boulder.

The community level economic benefits of action like code adoption are typically measured in terms of increased economic activity. The increased economic activity is created by the investment in energy efficiency that would occur in the community and the resulting customer utility savings. In addition, these benefits are enhanced by the fact that local investments in energy efficiency and additional expenditures facilitated by the savings offer generally higher economic multipliers. The appropriate economic multipliers for the study were obtained from the

1986 U. S. Department of Commerce Regional Input/Output Model (RIM) for Colorado. The economic multipliers utilized are:

Construction Activity (for DSM)	2.13
Business Services	2.08
Utility (electric and gas)	1.70

The net construction benefits calculation accounts for reinvestment of the construction costs by the business services sector assuming that DSM expenditures had not been made. The net savings benefit calculation similarly accounts for the reinvestment of the revenue for the sale of electricity by the utility assuming that DSM savings had not been realized by its customers. The net present value of net construction benefits (NCB) was determined to be $21,350, or:

NCB = $427,000 (2.13 - 2.08)
= $ 21,350

The net present value of net savings benefit (NSB) is $387,600, or

NSB = $1,020,000 (2.08 - 1.70)
= $ 387,600

The total net benefit is the sum of NCB and NSB, or $409,000.

Cost/Benefit Analysis of Exceeding Code

The objective of the economic analysis of exceeding ASHRAE 90.1 code requirements is to determine the economic viability of a commercial new construction DSM program in PSCo's service territory. This analysis accounts for the unique, cost-effective economics of new construction programs, and regional considerations.

The program level analysis is obtained by extrapolating the cost/benefit results with the projections of Boulder's commercial new construction growth. This analysis confirms the existence of significant, cost-effective DSM opportunities not captured by the ASHRAE 90.1 based code. The estimated net present value of exceeding the code costs and savings are based on implementing the most cost-effective packages of measures for each building type presented in section 6.3. The net present value of incremental cost is $1,868,000 (or $1.037 per square foot), and the net present value of savings is $2,729,000 (or $1.568 per square foot).

From the perspective that energy efficiency is an economic development tool, the overall community level economic benefits that would be leveraged by the city can be estimated in a simplistic analysis. The approach used is the same as for estimating the economic benefits of code adoption. The calculation of net construction benefits accounts for the reinvestment of the construction costs by the business services sector assuming that DSM expenditures had not been made. The net savings benefit similarly accounts for the reinvestment of the revenue for the sale of electricity by the utility assuming the DSM savings had not been realized by its customers. The net construction benefits are estimated to be $93,400, and the net savings benefits are estimated at $1,130,000.

Acknowledgments

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Endnotes

1. The economic assumptions utilized in all net present value calculations include: (1) 9% nominal interest rate, (2) 0% general inflation and fuel inflation rate, (3) enhanced and base case measures have no salvage value and no disposal cost, (4) enhanced and standard measures do not necessarily have the same useful life, (5) tax consequences are not considered, and (6) savings from efficiency do not degrade over time.

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